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CONTRIBUTIONS FOR SELECTION OF MEASUREMENT DEVICES OF PRODUCT QUALITY IN TERMS OF ECONOMIC FACTORS

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Abstract. *Product quality verification by measuring or control, although is not a process that will add value to a product, directly, can influence in an substantial manner management and technological decisions of every manufacturing process by becoming a reaction loop for the optimization of every technological process. In this paper it is presented the optimization methodology of measurement devices selection for product quality control based on overall costs. Presenting the total costs relation over several components and graphically representation of various variants that can appear in practice, depended on balance of several component costs from the total cost structure. Analyzing the way of optimized selection of several measurement or control devices for product quality verification.*
Keywords: *quality, measurement, control, optimization, costs*

1. GENERAL INFORMATION

In every type of human activity it can be found a knowledge component whose main purpose is to reflect almost perfectly the real technological processes through various laws of progress, which then gives the possibility to improve in conformity with desired and possible performances.
World products are always accompanied by measurement and control activities of various properties and characteristics which determines the product quality.
Product quality verification by measuring or control is not directly adding value to the product, this is done in order to approve the manufacturing process or the conformity of a specific characteristic imposed by the customer of manufacturer of the product. On the other way product quality verification results can have a direct influence over the managers, technological, constructive, conceptual, executional and maintenance decisions, verification being a reaction buckle (feedback) in every technological process for the product quality assurance.
From economical point of view, quality verification is a non-productive time, which increases the cost of manufacturing, for this reason this process must be limited to an absolute necessarily in each process step of the product manufacturing.
The problem of producing quality products is imposed by economic efficiency considerate. In this way it can be recognized an increased (by reason of raw materials and energy crises and markets globalization) balance of the entrance costs in the manufacturing process (raw materials, energy, purchased parts), which can get sometimes to over 50% of product final cost (finite products, spare parts, etc.) [4].
That's why, a major influence over the technological efficiency of the manufacturing processes is the optimized selection of the measurement and control devices for quality assurance.
The paper aims to present a serial of contributions with original elements for the total costs calculation of product quality verification and for the optimized selection of measurement and control devices with a graphical method, easy to use in most practical cases.

2. ACTUAL STATUS OF THE RESEARCH OVER THE FACTORS THAT CAN INFLUENCE THE SELECTION OF METHODS AND DEVICES FOR PRODUCT QUALITY MEASURING AND CONTROL

The most important factors, conditions, methodological and technical-economic characteristics can be found below [1]:

- parameters specific characteristics [3, 4];
- tolerances for specific parameters [1];
- measurement device reading precision for analogical and digital dial [1];
- error limits of the measurement/ control or the method used [1, 5];
- quality verification operation times [8];
- costs related to quality [3, 5, 8];
- quality inspector training level to operate high complex measurement/ control systems [6];
- production units (pre-serial, serial, high volume, special parts) [2];
- safety level of the device, elimination of the operator influence will increase the factor [6, 7];

The way that these factors are influencing the selection of the method and the device for quality verification are presented in general way in most of the cases.
For example, for the cost factor the expression is like this: the cost must justified and compensated by the device precision and the productivity and the method used; when is possible, for expensive devices, complex installations for measuring, they must be replaced with less expensive ones or by applying statistic methods.
For this reason it is imposed to optimize the selection of the measurement and control devices for product quality verification by applying mathematical models, as precise as possible, which takes in consideration all the parameters that can influence the economic efficiency of the method used.

3. OPTIMIZATION OF MEASUREMENT AND CONTROL DEVICES SELECTION IN TERMS OF TOTAL TIME COSTS FOR PRODUCT QUALITY VERIFICATION

Quality of a product depends in fundamental way of the design and conception activity of the quality verification devices. In this way was determine that 80% [4] from product quality it's agreed in the conception or selection of the verification device. Only 20% from the quality can be influenced (good or bad) by the execution process performance. Results, from the ones showed, that for optimization of variants selection of measuring or control devices for product quality verification, depends the success or the failure on the market of the product and implicit the economical agent which produced it.

Another method for determining the optimal quality verification method, measuring or control, can be done by using the next C_v relation, which takes in consideration other factors.

$$C_v = C_{pi} + n_p(N_{\frac{t}{v}} * C_{o.ech} + C_S) \qquad (1)$$

C_{pi} are the costs for product verification process preparation, where we can add: design, C_p, and execution, C_{ex}, costs for the verification device/s, the software used to run the equipment and the setup costs, C_{set}; n_p is the number of verified pieces; $N_{t/v}$ is the time norm of verification operation for product quality; $C_{o.ech}$ is the cost of one hour of product quality verification, including amortization and energy consumption, being electrical or any other nature: C_S are supplementary costs for maintaining and maintenance of the device used.
Relation (1) components are determined:

$$C_{pi} = C_p + C_{ex} + C_{set}, in\ Euro \qquad (2)$$

Costs of computerized design for the quality verification equipment it is determined with:

$$C_p = (C_{uc} + C_{usb} + C_{usdc} + C_{usds}) * t_p, in\ Euro/piece \qquad (3)$$

Cuc is the cost for computer utilization, in Euro/min; Cusb is the cost for using the base software, in Euro/min; Cusdc is the cost of using the dedicated software, for example Auto-CAD, in Euro/min; Cusds is the cost for using specialized software, in Euro/min; tp is the time necessary to design the equipment.

The terms from relation (3) are determined using the next calculation relations:

$$C_{uc} = \frac{P_{ac}+C_{sup.c}}{n_{ac}*134400} + S_{pr} + C_{en}, in\ Euro/min \qquad (4)$$

P_{ac} is the computer price, in Euro; $C_{sup.c}$ are the additional costs: maintenance, service, upgrade for the computer (15% from P_{ac}), in Euro; n_{ac} are the numbers of years declared for amortization (3-5 years); S_{pr} is the designer salary, Euro/ min; C_{en} energy consumption used for the computer utilization, in Euro/min.

$$C_{usb} = \frac{P_{asb}+C_{sup.sb}}{n_{asb}*134400}, in\ Euro/min \quad (5)$$

Pasb is the purchase price for the base software, in Euro; Csup.sb are additional costs to maintain and upgrade the base software (10% from Pasb), in Euro; nasb are the number of years in which the product will be amortized.

$$C_{usdc} = \frac{P_{asdc}+C_{sup.sdc}}{n_{asdc}*134400}, in\ Euro/min \quad (6)$$

Pasdc is the purchase price for the dedicated software; Csup.sdc are additional costs used for maintenance and upgrade (10% from Pasdc); nasdc are the number of years in which the product will be amortized.

$$C_{usds} = \frac{P_{asds}+C_{sup.sds}}{k*n_{asds}*134400}, in\ Euro/min \quad (7)$$

Pasds is the purchase price for the specialized design software, in Euro; Csup.sds are additional costs used for maintenance and upgrade (10% from Pasds); k is the coefficient of how much the software will be used in year ($0 \le k \le 1$); nasds are the number of years in which the product will be amortized.
In relations (3-7) was considered the equipment is used 8 hours every day.
Executions costs (manufacturing costs), C_{ex}, of the measurement or control device, are calculated with next relation [3]:

$$C_{ex} = C_M + S + R, in\ Euro \quad (8)$$

C_M are the costs for the materials used in the manufacturing of the product, determined with relation:

$$C_M = \sum m_S - \sum c_1 * k(m_S - m_{p)}, in\ Euro \quad (9)$$

C is the cost of one kg of material, in Euro; mS is the mass of the semi-manufactured parts used for production of the measurement or control device, in kg; c1 is the cost of 1 kg of recovered waste (reused); Euro/kg; k=0.8 – waste recover coefficient; mp mass of finite products from the measurement or control device produced.
Cost from remuneration offered to direct productive operators are calculated with relation:

$$S = \sum_{i=1}^{n} N_{t_i} * \delta_i, in\ Euro \quad (10)$$

Nti are the manufacturing (machining, measuring/ control, assembly, final assembly) time norms, in hours, necessary to produce one product; δi hourly salary, in Euro/ hour, used for each operation necessary; n number of operations used necessary.
Cost for the production facility, R, are determined proportional with the payments for the direct productive operators, maybe also other influence factors:

$$R = \frac{C_R}{100} * S, in\ Euro \quad (11)$$

CR is the percentage of general costs imposed by the manufacturer.
$N_{t/v}$ is the time norm for the product quality verification operation (calculated or measured).
$C_{o.ech}$ is the cost of 1 hour of working for the verification device, including amortization, energy consumption cost (electrical or any other energy used); C_S are additional costs for maintenance of the equipment used.
For both variants used for product quality control, measuring and control, it can be written next relation by attaching these 2 indexes, m and c.

$$C_{vm} = C_{pim} + n_p(N_{\frac{t}{v}m} * C_{o.echm} + C_{Sm)} \quad (12)$$

$$C_{vc} = C_{pic} + n_p(N_{\frac{t}{v}c} * C_{o.echc} + C_{Sc)} \quad (13)$$

By equaling both relations (12) and (13), it can be obtained the critical number of pieces for which the cost of product quality verification, np.cr, is equal for both measuring and control operations.

$$n_{p.cr}\frac{C_{pic}-C_{pim}}{\left(N_{\frac{t}{v}m}C_{o.echn}+C_{Sm}\right)-(N_{\frac{t}{v}c}C_{o.echc}+C_{Sc})} \quad (14)$$

For simplification:

$$N_{\frac{t}{v}m}C_{o.echm}+C_{Sm}=C_m \quad (15)$$

$$N_{\frac{t}{v}c}C_{o.echc}+C_{Sc}=C_c \quad (16)$$

Resulting in:

$$n_{p.cr}\frac{C_{pic}-C_{pim}}{(C_n)-(C_c)} \quad (17)$$

Cm and Cc are costs for product quality verification by measuring and control.
Each cost from general relation (17) can have bigger values or smaller values one compared to the other, depending on each condition. Therefore it can be found 4 cases:

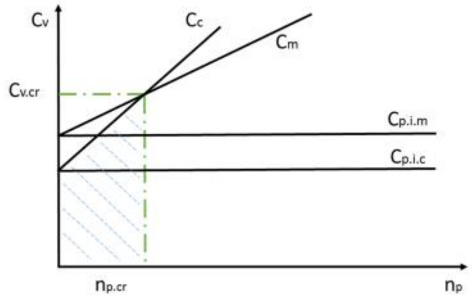

Figure. 1. Variation of product quality verification costs by number of pieces, when Cpim>Cpic; Cc>Cm

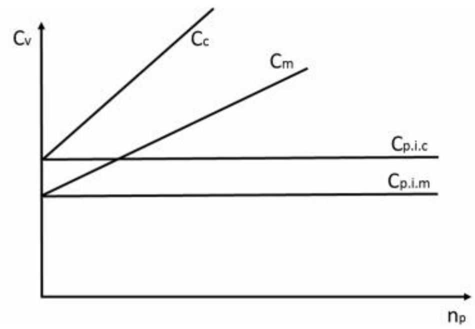

Figure. 2. Variation of product quality verification costs by number of pieces, when $C_{pic}>C_{pim}$; $C_c>C_m$

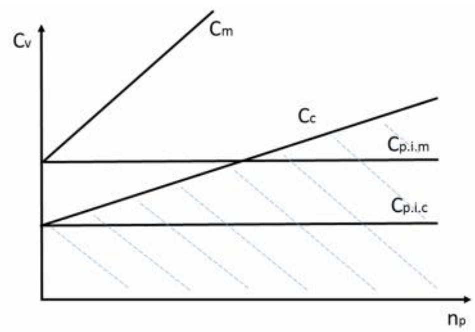

Figure. 3. Variation of product quality verification costs by number of pieces, when $C_{pim}>C_{pic}$; $C_m>C_c$

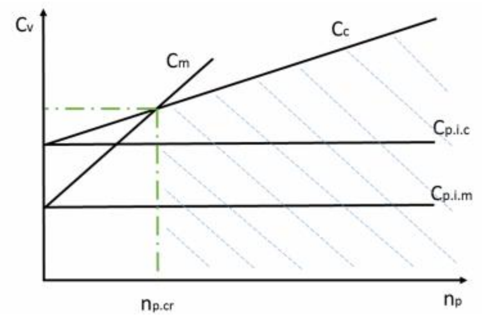

Figure. 4. Variation of product quality verification costs by number of pieces, when $C_{pic}>C_{pim}$; $C_m>C_c$

From graphs representation of these 4 possible cases, it can be determined the utilization of economical domain for the 2 variants used for product quality verification: measuring or control:
If $C_{pim}>C_{pic}$; $C_c>C_m$, minimal verification cost it is obtained by control if n_p is from 1 to n_{pcr}.
If $C_{pic}>C_{pim}$; $C_c>C_m$ minimal verification cost is obtained by measuring operation no matter how many pieces are verified.
If $C_{pim}>C_{pic}$; $C_m>C_c$, no matter the number of pieces, control operation is always the most economical.
If $C_{pic}>C_{pim}$; $C_m>C_c$, minimal verification cost is obftained with control operation, if $n_p>n_{cr}$.

CONCLUSIONS

Taking in consideration all presented in this paper, it can come off next conclusions and recommendations:

1. Selection of a verification device for product quality only based on personal production experiments, is not always sure that is the best option;
2. For efficiency in selection of the verification device it is necessary to take in consideration total costs which influence the cost of the final product.
3. From case to case, looking at the production plan it can be decided based on the paper presented, the critical product number from which one variant, from those analyzed, becomes more efficient.

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